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Original Research Article

Agronomic and Economic Evaluation of Common Bean-Tef in Double Cropping System

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Abstract: Double-cropping of cereals with legumes is a usual practice by small-holder farmers in southern parts of Ethiopia but crop compatibility and sequencing are the major problems for their soil fertility as well as profitability. Thus, it was important to conduct research on double cropping systems that can make the farmers more profitable on small land to reduce crop failure with current climate change. Thus, an experiment was done to evaluate the effects of these crops as double cropping on the productivity of tef and to evaluate the agronomic and economic value of common bean-tef in double cropping system for an improved production system at Shashemene district during the cropping season of 2022 and 2023 using RCBD design. The experiment consisting of twelve treatments including one common bean and three N rate with three tef varieties was sowed as the preceding and succeeding crop respectively and three sole tef varieties used as a control. The preceding crop the Hawassa dume common bean variety had 8 ton/ha dry biomass and 35 Qt/ha grain yield. The variance analysis showed that all the growth and yield parameters of tef except harvest index were significant such as Plant Height, Panicle Length, Straw Yield, Biomass yield, Grain Yield ($p<0.05$).

Keywords: Double Cropping, Recommended N, Common Bean-Tef, Bora, Hawassa Dume.

1. INTRODUCTION

Tef (Eragrostistef (Zucc.)) belongs to the grass family poaceae and it is among the major cereals of Ethiopia (Paff and Asseng, 2018). Ethiopia is the center of both the origin and diversification of teff and its domestication is anticipated to have happened somewhere in the range of 4000 and 1000 BC (Vavilov NI., (1951). It has the largest value in terms of both production and consumption in Ethiopia (Minten *et al.*, 2013; Tesfay and Gebresamuel., 2016). Tef in Ethiopia stands first in area coverage and second in total annual production next to maize and ranks the lowest yield compared with other cereals grown in Ethiopia (CSA, 2021; Assefa *et al.*, 2017; Tesfahun, 2018). The national tef productivity is 18.82 qt /ha (CSA, 2021; Tesfay and Gebresamuel, 2016). On the other hand, the common bean (Phaseolus vulgaris L.) is one of the most important pulse crops grown in Ethiopia in terms of both area and quantity produced. It stands second in area coverage and total annual production next to faba-beans and ranks fourth in yield compared with other pulses grown in Ethiopia (CSA, 2021).

Low soil nitrogen (N) availability is often the major nutrient factor limiting crop productivity

(Andrews *et al.,* 2004). Applying inorganic N fertilizer has become an important tool to increase crop yields and grain quality in intensive agricultural systems (Andrews *et al*., 2004). However, a large proportion of the applied N fertilizer is usually lost as a result of surface runoff, leaching, soil denitrification, volatilization, and gaseous plant emission. Therefore, N management is essential for economic yield, optimum water utilization, and minimum pollution of the environment (Corbeels *et al*., 1999). One of the solutions to increase soil nitrogen in environmentally friendly manner is a legume with a cereal double cropping system. Legumes are able to fix and incorporate nitrogen into the system and improve soil structure, avoiding the formation of a hardpan and promoting better aeration (Caviglia *et al*., 2004). Legumes increase soil fertility through the action of microorganisms, which are imperative to affect the soil properties, including soil biological, chemical, and physical properties (Vasconcelos *et al*., 2020). To maximal benefit from biological nitrogen fixation systems can be recognized through integrating legumes into agricultural systems in which the benefits of biological nitrogen fixation can be extended to crops and cropping systems (Kebede, 2020a). The well-known agricultural systems of integrating legumes into cropping systems include crop rotation, simultaneous intercropping, improved fallows, green manuring, relay cropping, and double cropping. Double cropping could maximize benefit from same area and season. It is a key to look for best combination and compatibility of crops to exhaust the opportunity from the system. It was reported that double cropping has many advantages, such as reducing the risk of field loss due to drought, insects, and disease, and obtain a better use of vertical space and time in limited farmland (Beuerlein, 2001).

Empirical data and simulations with the Agricultural Production Systems Simulator model were used to give insights into the N contribution, yield benefit to cereals, and overall economic performance of the inclusion of pulses into the double cropping (H. W. Cox *et al*., 2010). Legume crops contribute to 15% of the N in an intercropped cereal and mitigate the emission of greenhouse gases (GHGs) by reducing the application demand of synthetic nitrogenous fertilizers (S. K. Kakraliya *et al*., 2018). The result of Shuaibu YM *et al*., 2015 revealed that the application of 60kg N/ha as a top dress to sorghum grown on cowpea or soybean residue should be adopted by farmers in and around Bauchi state for higher yield. The cereal-only cropping was the most profitable but not the most sustainable; N deficiency reduced yield and protein after three crops. The rotation with the cereal immediately followed by a pulse crop was profitable without the need for fertilizer N. When the pulses were grown on fallowed ground (with cereals being double-cropped) economic returns were as good as, and potentially greater than, the cereal/double-crop pulses rotation. Well-grown chickpea and mung bean crops contributed 51 and 41 kg N/ha, respectively, to the subsequent cereal (H. W Cox *et al*., 1996). The finding by S. Mesfin *et al*., 2023, indicated that wheat yield increased by 2196, 1616, 1254, and 1065 kg ha−1, and the N uptake increased by 71.4%, 51.0%, 49.2%, and 29.8% in the faba bean-wheat, 'dekeko'-wheat, field pea-wheat and lentil-wheat rotation plots compared to the wheat continuous cropping, respectively.

Double cropping cereals after pulse cropping could be an alternative to increase the productivity of the crop, although double cropping of pulse with cereals was still under investigation. The practice of legume and cereal double cropping was common among smallholder farmers as a food source for humans. However scientific studies are rare despite potential advantages to enhance income and satisfy food sources for poor households. The study reported here sought to bridge this knowledge gap with a view to increasing the productivity of common bean/tef double cropping systems. Besides offsetting the production shortage of smallholder as well as large-scale agriculture common beans grown as double cropping with tef could have the potential to improve the productivity and the production of crops. Hence, there is a need to evaluate the effects of these crops as double cropping on the productivity of tef and to evaluate the economic and technical feasibility of common bean-tef in a double cropping combination for an improved production system at Shashemene Zuria area of Oromiya regional state, Ethiopia.

2. MATERIAL AND METHODS

2.1 Description of the Experimental Site

The field experiment was done in two years (2022 and 2023) at Shashemene district which is located between latitude at 7° 04' 50" N and longitude 38° 23' 00" E with an altitude of ranges from 1683 to 2742 m a.s.l and found in Oromiaya Regional State. The rainfall distribution during the year is bi-modal, with a dry spell period during June and July which, depending on its duration, may affect crop growth. The first Season is named 'Belg' the shortest one and takes place between March and May, while the second and the most important is 'Meher' between July and October. The maximum amount in mm is recorded at wendogenet (1111.29mm) but at Shashamane (862.56mm). The mean annual minimum to maximum temperature ranges from 11.47 and 26.51 °C, respectively. The soil textural area of the experimental area was Vitric Andosols with a pH of 6.23 (Tadesse H. *et al*., 2016).

2.2 Sources of Planting Material and Cultural Practices

The seed of Tef was obtained from the Debrezeyt agricultural research center, while the common bean crop that was used for the experiment was obtained from the Wendo genet agricultural research center. The Tef variety is commonly cultivated in the region with an average yield of 7-16 Q ha^{-1} as stated by Southern Nations, Nationalities and Peoples Regional State's Agriculture Bureau.

The land was prepared following a standard practice and the crop was grown as rain-fed. Before sowing the components, the land was plowed to prepare a suitable seed bed, and seeds of the common bean as well as tef were sown by hand with their spacing. For tef, the intra-row spacing will be 20 cm with line drilling and the common bean crop was planted 10 cm apart from each other and 40 cm between rows. At the time of planting, all plots received a basal application of recommended NPS for tef and common bean, respectively. Generally, crops in these studies were raised according to the standard cultural practices applicable to the areas. Each experimental plot size was 1.4 m in length and 4 m in width respectively.

2.3 Treatments and Experimental Procedure

The experimental materials used for this study were: used as preceding, succeeding crops, and N rate for tef. The crop used as preceding the common bean crop was selected based on their current and potential importance and mainly for their early maturity. The succeeding crop used was tef variety.

A factorial experiment consisting of the Hawassa-dume common bean variety was sowed as the preceding crop while the planting of three tef varieties with three N rates was used as the succeeding crop to see the effects of common bean and N rates on the production of tef varieties. The treatments of this experiment included the common bean Hawassa dume variety as preceding crop and Tef (Boset) with 100% N, Tef (Boset) with 75% N, Tef (Boset) with 50% N, Tef (Smada) with 100% N, Tef (Smada) with 75% N, Tef (Smada) with 50% N, Tef (Bora) with 100% N, Tef (Bora) with 75% N, Tef (Bora) with 50% N and sole of Tef varieties (Table 1). Hence, the experiment was laid out in randomized complete block design (RCBD) with factorial combination, where three varieties of Tef and three N rates plus sole Tef varieties as a control were arranged as a treatment, resulting into a total of 12 treatments replicated three times.

Table 1: Treatment combinations of N rates with Tef varieties in common bean and tef double cropping system

Treatment	''N ''rate	Tef varieties	Treatment combinations
1	100% (100 kg/ha)	Bora	T1
2	75% (75 kg/ha)	Bora	T2
3	50% (50 kg/ha)	Bora	T3
4	100% (100 kg/ha)	Boset	T4
5	75% (75 kg/ha)	Boset	T5
6	50% (50 kg/ha)	Boset	T6
7	100% (100 kg/ha)	Smada	T7
8	75% (75 kg/ha)	Smada	T8
9	50% (50 kg/ha)	Smada	T9
10	………	Sole Bora	T10
11	………	Sole Boset	T11
12	………	Sole Smada	T12

2.4 Data Collection on Common Bean

Days to 90% Physiological Maturity:

Days to physiological maturity will be recorded when about 90% of the plants reach physiological maturity based on visual observation. It will be indicated by senescence (turning to light yellow) of the leaves and vegetative parts as well as free threshing of grain from the grains when pressed between the finger and thumb.

Seed per Pod:

From ten plants the number of seeds per plant from the mature plants' parts will be randomly taken from the net plot area and counted at the time of harvesting.

Above-Ground Biomass (T/HA):

At maturity, the whole above plant parts, including leaves, stems and pods including seeds from the net plot area in each plot will be harvested and sun-dried until constant weight and then the above-ground biomass will be measured and expressed in kg ha-1.

Grain Yield (QT/HA):

After harvesting, threshed grains will be separated, cleaned, and weighed by electronic balance. The grain yield will be corrected to a moisture content of 11%, wet bases while moisture tester will be employed for measuring the moisture content.

Hundred Seed Weight (g):

Hundred seed weight will be counted by the electronic counter and weighed by electronic balance later 100-seed weight will be expressed in grams.

2.5 Data Collection on Tef

Plant Height of Tef:

At the time of maturity plant height of 10 selected plants will be taken randomly from the net plot area of each plot then the height will be measured from the ground to at terminal stem.

Days to 50% flowering: days to flowering will be recorded when about 50% of the plants in a plot produce flowers.

Days to 90% Physiological Maturity: when the tef plant is 90% matured Panicle length: measure the length of the panicle by using a meter.

Above Ground Biomass Weight (Qt ha^{-1}):

At the time of maturity, the whole above plant parts, including leaves, stems including seeds from the net plot area in each plot will be harvested and oven-dried at 100oc for 24 hours until constant weight and then the above-ground biomass will be measured and expressed in kg ha-1.

Grain Yield (Qt ha^{-1}):

After harvesting, threshed grains will be separated, cleaned, and weighed by electronic balance. The grain yield will be corrected to a moisture content of 12.5 %, wet bases while a moisture tester will be employed to measure the moisture content.

2.6 Economic Analysis

The partial budget analysis will include the average yield for each treatment, adjusted yield, and gross benefit. Then dominance analysis will be carried out to compare the increase in terms of cost that varies with its respective benefits.

2.7 Data Analysis

All data will be subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design using SAS (SAS, 2002). The least significant difference (LSD) test at 5% level of probability will be also used for mean separation as procedure described by Gomez and Gomez, (1984) and the linear model of RCBD will be used.

3. RESULTS AND DISCUSSIONS

3.1 The Variance Analysis of Major Traits of Tef Varieties in the Double Cropping System

The analysis of variance showed that all the agronomic parameters were significant such as plant height, panicle length, straw yield, and Biomass yield. However, the grain yield and harvest index had no significant difference between the treatments in the 2022 cropping season ($p<0.05$). The result of mono-cropped tef varieties is that the variety Boset has significantly the longest height compared to the variety Bora and Semada, similarly, the result of (Yazachew G. *et al.*, 2021) showed that the mean performance of the plant height showed that the variety Simada (88 cm) is the shortest and Boset had 97 cm long. On the other hand, the double-cropped Boset plant height had an increasing trained with increasing N rate other than the two varieties, but 100% and 75% N rates had no significant difference in Boset plant height. However, the varieties Bora and Semada had inconsistent plant heights trained at an increasing N rate. Similarly, the mono-cropped tef variety Boset had the longest panicle length than the Bora and Smada, here also the variety Boset had an increasing trained with increasing N rate in the double-cropped system. But the panicle length of Bora and Smada had variable trained with increasing N rate, here the rate of N had no significant effect on the Smada variety, whereas similar to plant height the panicle length of the Bora variety had the longest panicle length at 100% N rate and the shortest was resulted due to 75% N rate rather than 50% N. (Table 2).

Table 2: Effect of Nitrogen rate and Tef varieties on growth and yield components of tef in double cropping system during the 2022-cropping season

Tret	Treatment	PH (cm)	PL (cm)	SY (kg)	BY (kg)	GY (kg)	HI (%)
1	100% (100 kg/ha) + Bora	95.87ab	35.07ab	7109.2b	9233.3b	2124.1	23.187
2	75% (75 kg/ha) + Bora	56.4I	20.4e	4274e	5705.8e	1431.8	24.817
3	50% (50 kg/ha) + Bora	85.2cde	28.73c	6130.9bcd	8225bcd	2094.1	25.83
4	100% (100 kg/ha) + Boset	102.2a	38.67a	8803.6a	11371.7a	2568.1	22.387
5	75% (75 kg/ha) + Boset	98.13ab	36.67ab	7228.1ab	9004.2b	1776.1	19.51
6	50% (50 kg/ha) + Boset	90.67bcd	29.6c	7143.5b	9029.2b	1885.6	20.697
7	100% (100 kg/ha) + Smada	72.13gh	28.47c	5220.5cde	7033.3cde	1812.8	25.86
8	75% (75 kg/ha) + Smada	82.27def	29.27c	6664.5bc	8566.7bc	1902.1	22.53
9	50% (50 kg/ha) + Smada	79.07efg	27.13cd	6327.7bcd	7987.5bcd	1659.8	21.41

Tret	Treatment	PH (cm)	PL (cm)	SY (kg)	BY (kg)	GY (kg)	HI (%)
10	Sole Bora	76.2fgh	26.93cd	5846.5bcde	7500bcde	1653.5	21.433
11	Sole Boset	91.8bc	31.47bc	6212.1bcd	7683.3bcd	1471.2	19.743
12	Sole Smada	67.33h	22.0de7	4991.3de	6550de	1558.7	24.09
	LSD	8.96	5.45	1604.2	1857.3	694.15	7.87
	CV	6.37	10.89	14.97	13.45	22.42	20.54
	Sig	***	***	***	***	NS	NS

Plant Height (PH), Panicle Length (PL), Straw Yield (SY), Biomass yield (BY), Grain Yield (GY) and Harvest Index (HI)

The analysis of variance showed that the variety Boset significantly had the highest straw and biomass yield as compared to Bora and smada variety in monocropped system. On the other hand, the variety Boset had consistant trained with increasing N rate when double cropped with common bean as precursor crope. But the variety Bora and smada had variable trained with increasing N rate for instance Bora had the highest straw and biomass yield at 100% N rate and the lowest at 75% N rate instead of 50% N. Even if non-significant difference the variety Smada had the highest and the lowest straw and biomass yield resulted from 75% and 100% N application respectively. The result showed that there was no significant straw and biomass yield difference between 100% and 50% N application for the Bora and variety, 75% and 50% N application for the Boset variety. This result indicated that no need to apply a full dose of the recommended N application for Tef when it grew in a double cropping system with a common bean used as a precursor crop. The analysis of variance revealed that the grain yield and harvest index had no significant difference for the 2022 cropping season. Even if insignificant result of grain yield between tef varieties, the variety Bora had the highest as compared to the two varieties in the mono-cropped system. However, due to N application from precursor crop residual N and 100% recommended N for Boset had the highest grain yield and a slight difference with 100% and 50% N applied for Bora variety.

Table 3: Effect of Nitrogen rate and Tef varieties on growth and yield components of tef in double cropping system during the 2023-cropping season

Tret	Treatment	PH (cm)	PL (cm)	SY (kg)	BY (kg)	GY (kg)	HI (%)
1	100% (100 kg/ha) + Bora	86.80a	38.27abc	3014a	4813a	1799b	37.37f
2	75% (75 kg/ha)+ Bora	88.40a	41.13a	1682b	3842b	2161a	56.23ab
3	50% (50 kg/ha)+ Bora	84.13ab	41.62a	2810a	4893a	2083a	42.57ef
4	100% (100 kg/ha)+ Boset	77.27abc	34.00abcde	1319d	2838cd	1519cd	53.81ab
5	75% (75 kg/ha)+ Boset	73.93abc	30.13cde	1670b	2982cd	1312defg	44.04def
6	50% (50 kg/ha)+ Boset	83.33ab	37.4abcd	1222d	2928cd	1706bc	58.29a
7	100% (100 kg/ha)+ Smada	69.47bc	32.33bcde	1371d	2523de	1151fg	45.77cde
8	75% (75 kg/ha)+ Smada	66.27c	28.67de	1303d	2645d	1342def	51.03abcd
9	50% (50 kg/ha)+ Smada	68.87bc	30.60cde	1057d	2162e	1104g	51.98abc
10	Sole Bora	80.53abc	40.87ab	1772b	3129c	1358def	43.58ef
11	Sole Boset	77.07abc	34.80abcde	1308d	2573de	1264efg	49.35abcde
12	Sole Smada	65.13c	28.47e	1220d	2625de	1405de	53.35ab
	LSD	16.1	8.75	388	480	218	7.35
	CV	12.36	14.83	13.93	8.96	8.47	8.86
	Sig	NS	***	***	***	***	***

Plant Height (PH), Panicle Length (PL), Straw Yield (SY), Biomass yield (BY), Grain Yield (GY) and Harvest Index (HI)

According to the result of the 2023 data the maximum plant height was recorded at Bora tef variety with 75% of recommended N which was not significantly different with the sol as well as N applied treatments. But the panicle lengths of the varieties with different N rates were significantly different and the longest panicle length was recorded at half N application of the Bora variety which was not different with full and 75% recommended N applied for the Bora variety. Similarly, the maximum panicle length of the Boset variety was also recorded at half dose of N recommended but not different in panicle length with a full dose of N recommended.

The analysis of variance revealed that the maximum straw yield was recorded at full dose N application of the Bora variety which was not significantly different with half N application. On the other hand, significant maximum dry biomass was recorded at half dose of N applied for Bora variety which was not significantly different from the full dose of N applied plot. The highest straw and biomass yield was recorded from the Bora variety however Boset and Smada produced the lowest and significant straw and biomass yield in the monocropped system as compared with the Bora variety.

The analysis result of grain yield of Bora variety showed that significantly the highest yield with 75% of recommended N which is not significantly different with half dose of recommended N. However, the mono-cropped tef varieties had no significant difference in grain yield. The analysis of variance showed that significantly the highest harvest index was indicated on the variety of Boset with a half dose of recommended N. This result indicated that the variety Smada and Boset in the monocropping system had the highest and non-significant Harvest index.

Table 4: Mean of the two-year Effect of Nitrogen rate and Tef varieties on growth and yield components of tef in double cropping system during 2022 cropping season

Tret	Treatment	PH (cm)	PL (cm)	SY (kg)	BY (kg)	GY (kg)	HI (%)
1	100% (100 kg/ha) + Bora	91.33a	36.67a	50.62a	70.23ab	19.62ab	30.28
2	75% (75 kg/ha)+ Bora	72.40bcd	30.77ab	29.78e	47.74e	17.96abc	40.52
3	50% (50 kg/ha)+ Bora	84.67abc	35.18a	44.71ab	65.59abc	20.89a	34.20
4	100% (100 kg/ha)+ Boset	89.73ab	36.33a	50.61a	71.05a	20.43a	38.10
5	75% (75 kg/ha)+ Boset	86.03abc	33.40ab	44.49ab	59.93bcd	15.44cd	31.78
6	50% (50 kg/ha)+ Boset	87.00abc	33.50ab	41.83abc	59.79bcd	17.96abc	39.49
7	100% (100 kg/ha)+ Smada	70.80cd	30.40ab	32.96cde	47.78e	14.82cd	35.82
8	75% (75 kg/ha)+ Smada	74.27abcd	28.97ab	39.83bcd	56.06cde	16.22bcd	36.78
9	50% (50 kg/ha)+ Smada	73.97abcd	28.87ab	36.93bcde	50.75de	13.82d	36.70
10	Sole Bora	78.37abcd	33.90ab	38.09bcde	53.15de	15.06cd	32.51
11	Sole Boset	84.43abc	33.13ab	37.61bcde	51.28de	13.68d	34.55
12	Sole Smada	66.23d	25.27b	31.06de	45.87e	14.82cd	38.72
	LSD	10.254	5.2352	8.98	10.45	4.03	10.497
	CV	7.575236	9.60	13.29	10.91	14.23	9.88
	Sig	***	**	***	***	*	NS

Plant Height (PH), Panicle Length (PL), Straw Yield (SY), Biomass yield (BY), Grain Yield (GY) and Harvest Index (HI)

According to the combined analysis of the two-year data except the harvest index, all the listed parameters were significantly different. The maximum plant height was recorded at Bora tef variety with a full dose of recommended N which was not significantly different with all treatments except 75% recommended N for Bora, full dose of N for semada, and sol smada. Similarly, the longest panicle length was indicated at full dose of N application for Bora variety that's not significantly different with all listed treatments except the sol smada variety. Even if not significantly different the variety sole Boset was the longest height of the two varieties. In contrast, the variety Bora had the longest panicle length compared to the two varieties.

The highest straw yield was recorded at the full dose of the recommended N to Bora variety and this result had not significant difference with all N-treated Boset variety and half dose of recommended N application for Bora variety. However, the maximum biomass was recorded at the full dose of N recommended Boset variety, a similar result was reported by (Tamirat W., 2021) found that the highest biomass yield was attained from the maximum N ha^{-1} application, While the lowest biomass was obtained from the control treatment. However, this result was not significantly different from a full and half dose of the recommended N of the Bora variety. Unlike the semad and Bora varieties, there is an increasing trained of straw and biomass of the Boset variety with an increasing N rate. Even if non-significant difference in straw and biomass yield with sole tef varieties Bora showed the highest result as compared with the two varieties.

On the other hand, the maximum grain yield was recorded from half dose of the recommended N of the Bora variety which was not significantly different from the full dose of the recommended N of Bora and Boset varieties, 75% of the recommended N of Bora, and half dose of the recommended N of Boset variety. Because of economic feasibility, the treatment half dose of the recommended N of the Bora variety is recommended for the area, this result is similar to the report of (Berhe H, *et al.*, 2020) which stated that the highest grain yield was recorded at 60 to 90kg N ha-1 of N fertilizer rates. Based on this trend and the economic point of view, it would be more profitable to use 60kg ha-1 N rates instead of, 90 and 120kg N ha-1. So, the combined analysis tells us the variety Bora shows a good result in almost all parameters however there is a similar result with the variety of Boset. On the other hand, the full dose of recommended N showed the maximum result in almost all parameters, similarly (Yohanis A. *et al.*, 2020) reported that the mean value of all parameters of teff was significantly increased in response to an increasing rate of nitrogen fertilizer as well as varieties. However, the half dose of N applied plot had no significant difference in value in almost all parameters of the Bora and Boset varieties. In general, using the variety Bora with a half dose of recommended N after harvesting the common bean makes the farmers more profitable by reducing the costs of N fertilizer.

3.2 Analysis of Variance of Major Traits of Common Bean in the Double Cropping System

The mean result of the two-year data from Hawassa dume common bean variety around shashemene area had 15.46 pod per plant, all most 6 grain seed per pod, 8-ton dry biomass yield, 35 quntal grain yield, 20 grams of hundrund seed and 45% harvest index. In addition to this result the common bean can reduse the need of Nitrogen by half for the subsequent tef crop in double cropping system.

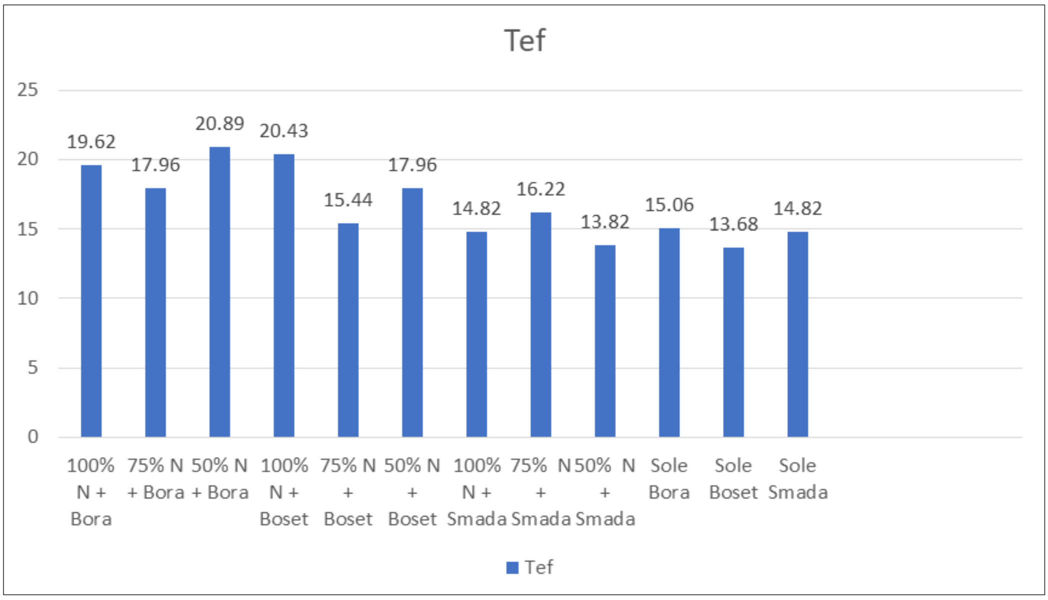

Figure 1: Yield responses (Qt/ha) of Tef for different Nitrogen rates in double-cropped with common bean

In general, the highest grain yield of tef was recorded from the Bora tef variety with half dose of recommended N (20.89 Qt/ha) but this result had no significant difference with the double-cropped Boset with full dose of recommended N (20.43 Qt/ha). This result indicated that the production of tef after harvesting common bean can reduce the nitrogen need of tef by almost 50%, in other words cropping Bora tef variety after harvesting Hawassa dume common bean variety has 50% nitrogen costs discount in tef production.

3.3 Economic Analysis

The results of the partial budget analyses and the data used in developing the marginal rate of return are given in Table 5. The result of total variable cost (TVC) revealed that the Boset tef variety treated with 75% recommended N costs less than other common bean-tef varieties combinations plots. The highest gross field benefit (GFB) and net benefit (NB) were obtained from half dose of recommended N for Bora tef variety (402287.95 and 332770.05 ETB ha^{-1}) respectively. On the other hand, the next highest gross field benefit (GFB) and net benefit (NB) were obtained from full dose of recommended N for Boset variety in double cropping system (389527.70 and 318213.80 ETB ha^{-1}) respectively. This result showed that sowing the variety Bora or Bose after Hawassa dume common bean variety arounde shashemene area in a double cropping system is more profitable tef variety.

Table 5: Marginal rate of return of common bean-tef double cropping system

Treatment	TFAY (kg)	CMAY (kg)	TFADY (kg)	CMADY (kg)	TVC (Birr)	NB (Birr)	GFB (Birr)	CBR	MRR
Boset + 75% N	1543.82	3516.67	1396.02	3234.36	68552.38	228344.35	296896.73	4.33	0.03
Smada + 75% N	1622.10	3516.67	1553.72	3234.36	68688.90	247131.17	315820.07	4.60	3.12
Smada + 50% N	1382.00	3516.67	1438.99	3234.36	68759.69	233293.13	302052.82	4.39	0.83
Bora + 75% N	1796.28	3516.67	1743.75	3234.36	69423.17	269201.28	338624.45	4.88	6.03

Treatment	TFAY (kg)	CMAY (kg)	TFADY (kg)	CMADY (kg)	TVC (Birr)	NB (Birr)	GFB (Birr)	CBR	MRR
Bora + 50% N	2088.57	3516.67	2274.28	3234.36	69517.90	332770.05	402287.95	5.79	15.16
Boset + 50% N	1795.95	3516.67	1744.77	3234.36	69979.51	268767.02	338746.53	4.84	5.51
Bora + 100% N	1961.59	3516.67	1501.38	3234.36	70122.49	239417.57	309540.06	4.41	1.50
Smada + 100% N	1481.96	3516.67	1681.43	3234.36	70773.52	260372.31	331145.83	4.68	3.95
Boset + 100% N	2043.40	3516.67	2167.95	3234.36	71313.90	318213.80	389527.70	5.46	10.35

ETB = Ethiopian Birr; CBR=Cost benefit ratio, GFB = Gross field benefit; MRR = Marginal rate of return; NB = Net benefit; TVC = Total variable cost; TFAY = Tef Average yield; CMAY= Common bean Average yield; TFADY= Tef Adjusted yield; CMADY= Common bean Adjusted yield.

The dominance analysis, in this experiment, showed that the three tef varieties treated with different N rate of net benefit return was higher than the treatments costing lower than the listed treatments, that means all the treatments were the un-dominated ones (Table 4). The analysis of the marginal rate of return (MRR), on the other hand, showed the return per unit production cost was highest from half dose of recommended N of Bora (MRR = 15.16) (Table 5). Planting the Bora tef variety with half dose of recommended N after common bean harvesting in a double cropping system at Belg and Mehere season around shashemene expect to recover 1 Birr and obtain an additional 15.16 Birr return for 1 invested Birr during the production time. This result showed that sowing the Hawassa dume common bean variety at belg season and then the Bora tef variety with half dose of recommended N in a double cropping system was the most successful and profitable production system compared to the rest of the treatments.

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